Title: Human Factors Reach Comfort Determination Using Fuzzy Logic.

Frank A. Wojcik

United States Army Tank Automotive Research, Development and Engineering Center

frank.wojcik@us.army.mil

Abstract:

Integration of electronic equipment into confined spaces can create issues with the comfortable movement of an individual that must occupy and work within that space. The areas of movement that may be affected include, but are not limited to ingress, egress, reach, or clearances within that confined space. Complicating the confined space is if the space must conform to a large segment of the physical population (i.e. 5th percentile female through 95th percentile male).

Fuzzy logic is used to define the range of comfort for the reach of a 5th percentile female and the range of comfort for the reach of a 95th percentile male. Utilizing the computer software, the high comfort zone shared by the 5th percentile female and 95th percentile male is identified, as are good comfort zones and low comfort zones. Defining these zones will create envelopes of good design practices which will account for the space required by the operator for basic physiological functions, in this case the individual's reach. The models are verified using hypothetical data and real data when possible. Data sources are provided. Computer simulation results of the proposed model are presented.

1.Introduction:

Human Factors Engineering (HFE) concerns many areas not limited to but including eye search patterns, visual pick-up, egress, clearances, and reach. These areas must encompass a wide variety of body shapes and sizes. The job of the designer or engineer is to provide a workspace environment that will work for the largest segment of the human population. Many modern methodologies are adaptations of methods developed when drawing boards were used to sketch out and define these workspaces whether in a vehicle, in front of machinery, or in an office environment. These parameter approaches can give clearances, movement envelopes, reach or optimal control positions, but don't give comfort levels of the operators in those workspaces. That "feel" for the workstation environment is the focus of this study. Fuzzy models are used to roughly define the comfort level and can help optimize the design accordingly to accommodate a large population distribution.

The proposal of this paper is the use of fuzzy methods to demonstrate how a comfortable reach zone can be defined to cover a large segment of the human population: the segment between the 5th percentile female and the 95th percentile male. Defining the best comfort zone using fuzzy logic can better approximate the human comfort side of the equation. Utilizing this approach has implications far beyond the simple example used to illustrate this idea. Capitalizing on the many publically available anthropomorphic studies performed by groups such as ANSI, ISO, or NASA, fuzzy logic could be used to define comfortable reach, comfortable clearances, comfortable positions, and thus, comfortable work zones. Equally important to the above items is their application to a confined work zone. The fuzzy logic solution could assist getting the best possible comfort for an operator within a confined space. Again, these examples are beyond what is covered in this paper, but show the expanded possibilities of these fuzzy logic techniques if applied across the entire range of HFE.

2.Approach:

The determination of the best reach "comfort zone" between the 5th percentile female and the 95th percentile male was performed using fuzzy logic. Software was

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **17 DEC 2009**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**

4. TITLE AND SUBTITLE **Human Factors Reach Comfort Determination Using Fuzzy Logic**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) **Frank A. Wojcik**	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **US Army RDECOM-TARDEC 6501 E 11 Mile Rd Warren, MI 48397-5000, USA**	8. PERFORMING ORGANIZATION REPORT NUMBER **20251RC**
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) **TACOM/TARDEC**
	11. SPONSOR/MONITOR'S REPORT NUMBER(S) **20251RC**

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**SAR**	**4**	

used for this study. Using the general case example as a guide, the logic is laid out for constructing the program with the inputs, outputs and rules governing the input terms and the output terms (Fig 1).

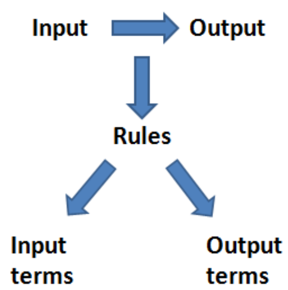

Fig 1: [13]Fuzzy General Case

The two input terms in this case were the 5th Percentile Female Reach and the 95th Percentile Male Reach. The Output term in this case was Comfort. The data was collected from multiple sources including: NASA-STD-3000, MIL-HDBK-759B, MIL-STD-1472D, DOD-HDBK-743A, and FMVSS-101 (for a complete list, see the References section).

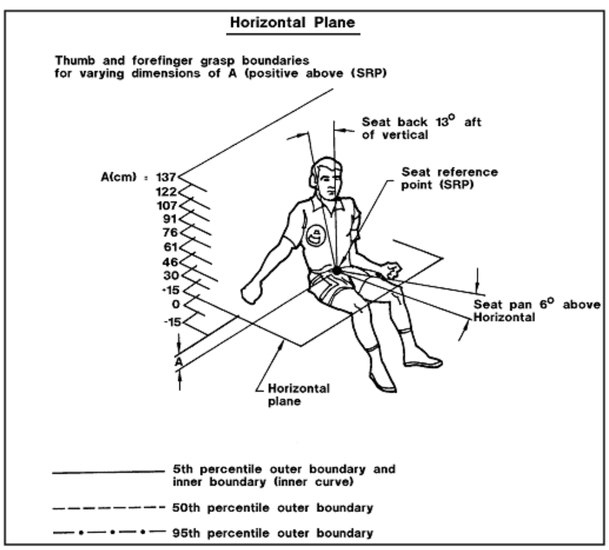

Fig 2: [8] NASA-STD-3000, fig 3.3.3.3.1-1: Grasp Reach Limits With Right Hand for American Male and Female Populations – Horizontal Planes

The ranges used in the fuzzy analysis were defined from a combination of the above resources (Fig 2). For example, the 5th Percentile Female's reach minimum was approximated at her torso measurement and her maximum was approximated at her extended reach. The multiple documents contained different base reference points – thus the approximations. This approach is parametric in its design and uses sub-zones within the overall reach zone to define the three levels of reach: Minimum, Average, and Maximum. The same methodology is applied to the 95th Percentile Male using the applicable male data. Logical rules are then applied to the inputs using If-Then statements within the software editor (provided in the *Software* section). The Output was split into three variables: *Minimum*, *Average*, and *Maximum*.

3.Comparison to Existing Approaches

The analysis approaches that most closely resemble the proposal of this paper do not openly admit to using fuzzy sets. This may be due to proprietary reasons, but if they do not use fuzzy, it leaves a gap in the analysis that fuzzy methods can fill.   One commercial enterprise's methodology uses three-dimensional solid parametric modeling, but the enterprise makes no public mention if fuzzy methods are used in the software. Likewise, a second commercial enterprise advertises human machine interaction design expertise. This is a modification of a typical approach of collecting information from experts, but utilizes multiple disciplines (Human Factors, Graphic Design, Engineering, etc.) inputs into CAD reviews which checks to a set of design rules. The second enterprise makes no mention of fuzzy methods in this approach.

The fuzzy logic approach differs from the CAD-driven approach in that the CAD-driven approach does not try to define a comfort level, just parameters. The fuzzy rules created can be driven back into the CAD software to define the comfort level of the design as it is in the process of design. This comfort definition could be used with the parametric approach to more quickly come to a design solution. For instance, a right-hand reach zone could be determined through fuzzy logic and applied to the CAD location to develop the best environment for the operator at that work station. Different zones could be defined in red-yellow-green terms to signify the best solutions based on comfort across the range from 5th Percentile Females to 95th Percentile Males.

4.Software:

Software is utilized in the determination of workspace reach comfort. The model was set up based on a general case (Fig 1). The editor was modified to include two inputs: one labeled 5^{th}_F_Reach (5^{th} Percentile Female) and the other labeled 95^{th}_M_Reach (95^{th} Percentile Male). The output was labeled Comfort (Fig 4) and was divided into three zones: *Low*, *Good*, and *Great*. The Gaussian curve was used for both the inputs and the output as a way to note the transition between the 5^{th} Percentile Female reach zones and the 95^{th} Percentile Male reach zone. The Triangular function appeared too drastic a transition for HFE usage. The reach values for the 5^{th} Percentile Female and 95^{th} Percentile Male were derived from the NASA, DOD, and MIL documents (Fig 5).

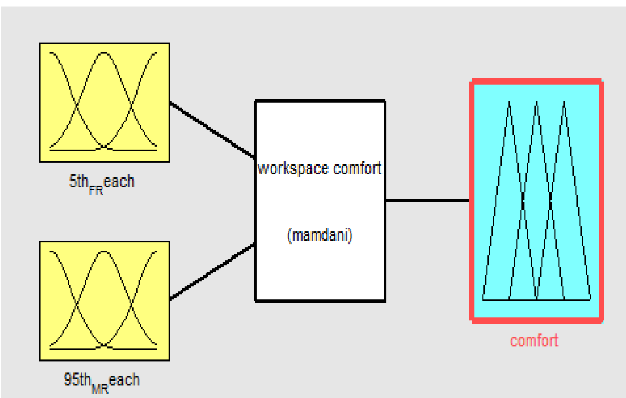

Fig 4: [13] Software Editor

	Min Reach	Avg Reach	Max Reach	Range
5th % F	15-25	25-50	50-68	15-68
95th % M	25-45	45-68	68-90	25-90

Fig 5: Reach values used in the Editor.

This program utilizes four rules in its calculations:

1) *If (5^{th} is min) or (95^{th} is max) then comfort is low.*

2) *If (5^{th} is avg) and (95^{th} is average) then comfort is great.*

3) *If (5^{th} is max) and (95^{th} is min) then comfort is good.*

4) *If (5^{th} is min) and (95^{th} is min) then comfort is good.*

5.Results:

The results show a surface curve that indicates a zone of low comfort that should be avoided, a good zone that is not optimal, but workable by both extremes, and a great zone that falls within the highest comfort zone of both extremes (Fig 6).

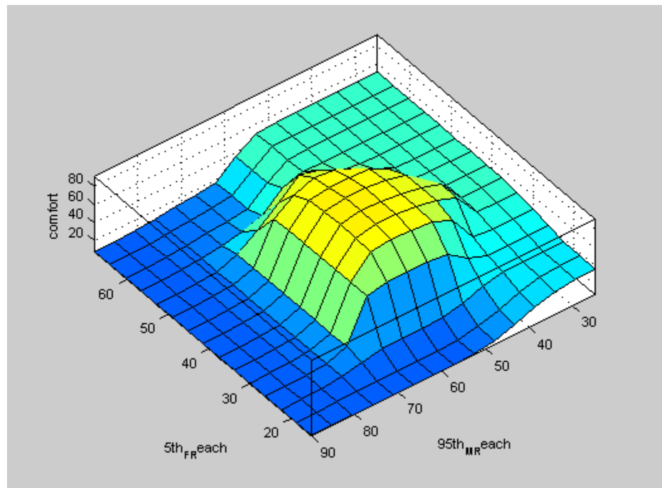

Fig 6: [13] Fuzzy Surface Viewer: *Low (lowest zone), Good(middle zone), Great(peak zone)*

6.Results Discussion:

The results are not unexpected. The *Great* zone indicates a best solution for both the 5^{th} Percentile Female and the 95^{th} Percentile Male where there is an intersection of optimal work (reach) areas. That area is approximately 25% of the total area which would also be expected based on the values for reach for each extreme. The zone that falls under the *Good* category falls within a better zone for 50^{th} Percentile operator, but is less than optimal for the two extremes. The *Low* zone is either out of reach for the 5^{th} Percentile Female or too close to the torso of the 95^{th} Percentile male. Those areas should be avoided by the design engineers when looking at a workable reach zone for the highest population distribution.

7.Conclusion and Future Research:

The use of fuzzy methods can help define a zone of comfortable reach which then can be applied with a CAD model to create optimum placement of controls, seating, and general working space. This example, though limited in scope could be applied further and with greater depth and detail to the workspace. There exists a tremendous amount of data from multiple sources that could be mined to create a 3D envelope. A more inclusive HFE set or sets of data could have fuzzy logic methods applied to define different workspaces with more fidelity within a CAD environment. If this was driven into designs early in development cycles, there could be tremendous benefits seen in costs and schedules. It could also be applied to existing designs that would benefit the operators within the workspace if it could be re-configured using these fuzzy methods effectively. Fuzzy techniques as applied to HFE could also help standardize HFE practices and apply them across the entire range of HFE to a particular design. It could become another analysis tool. The future applications are numerous.

8.References:

[1] Singh, Harpreet. Fuzzy Logic, ECE 5995. Wayne State University. Lecture (14,17,21,24 October 2009)

[2] United States. National Aeronautics and Space Administration (NASA). NASA-STD-3000B: Man-Systems Integration Standards (July 1995).

[3] United States. Department of Defense (DoD). DOD-HDBK-743A: Anthropometry of US Military Personnel (13 Feb 1991).

[4] United States. Department of Defense (DoD). MIL-HDBK-759B: Human Factors Engineering Design for Army Material (30 Oct 1991).

[5] United States. Department of Defense (DoD). MIL-STD-1742D: Military Standard, Human Engineering, Design Criteria for Military Systems, Equipment, and Facilities (1 Mar 1989).

[6] United States. National Highway Transportation Safety Administration (NHTSA). Federal Motor Vehicle Safety Standards. FMVSS-101. Controls, Telltales, and Indicators (17 Aug 2005).

[7] M.S. Sanders, E.J. McCormick, Human Factors in Engineering and Design, McGraw-Hill, New York, 1993.

[8] United States. National Aeronautics and Space Administration (NASA) Reference Publication 1024: Anthropometric Source Book, Volume 1: Anthropometry for Designers, Staff/Webb Associates, NASA (July 1978)

[9] Society of Automotive Engineers, SAE J833 USA: Human Physical Dimensions, Const. & Ind. Machinery Tech. Committee, Society of Automotive Engineers (Dec 1983).

[10] GENPAD® (Generic Parametric Design)Visteon website, retrieved 1-December-2009 http://www.visteon.com/company/capabilities/genpad.html

[11] HMI Design Expertise, Johnson Controls website, retrieved 1-December-2009 http://www.johnsoncontrols.com/publish/us/en/products/automotive_expertise/Electronics/HMI_Design_Expertise.html

[12] U.S. Army MANPRINT website, reviewed 7-Dec-2009 http://www.manprint.army.mil